# The early years at BNL

- The post-docs
  - Leo Stodolsky, Eduardo de Rafael, Colin Wilkin, Brian Martin, Benny Lautrup, Farzam Arbab, Jack Donohue, Bob Brown, Paul Kantor, Dubrovko Tadic, Min-shi Chen, Frank Paige

- The senior staff

Gian Carlo Wick ~55
Ronnie Peierls ~30
Larry Trueman ~30

- The post-docs
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Gian Carlo Wick ~55

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R.M. Sternheimer

- # The post-docs

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Phys. Rev. 160, 1296 - 1305 (1967)

# Spin Dependence of High-Energy Scattering Amplitudes. I

A. H. Mueller and T. L. Trueman
*Brookhaven National Laboratory, Upton, New York*
Received 24 March 1967
A formalism, useful for discussing spin dependence of scattering amplitudes in terms of complex angular momentum, is given. The question of the spin dependence of elastic scattering amplitudes, its relationship to coupling to Regge poles, fixed poles in the angular-momentum plane, and superconvergence relations are discussed. It is concluded that general principles permit the coupling at a vertex of a Regge pole of integer spin $J0$ and two particles whose spin projection is greater than $J0$, provided the Regge pole has the wrong signature to be a particle of spin $J0$. In particular, the Pomeranchuk trajectory at $t=0$ ($J0=1$) can flip helicities by two or more units and hence yield spin-dependent cross sections. Several models which support this conclusion are given. The possibility that a particular Regge pole's coupling does vanish is not ruled out, however.

Phys. Rev. 160, 1306 - 1312 (1967)

# Spin Dependence of High-Energy Scattering Amplitudes. II. Zero-Mass Particles

A. H. Mueller and T. L. Trueman
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Received 14 April 1967
The discussion of spin dependence at high energy is extended to the case of zeromass particles. Crossing relations for zero-mass particles are derived, showing that the helicity of massless particles is simply reversed under crossing. These are used by way of a Pomeranchuk-Martin-type theorem to obtain restrictions on the highenergy spin dependence. The problem of fixed poles in the angular-momentum plane and the coupling of the Pomeranchuk trajectory to photons is discussed. It is shown that if there are no fixed poles at positive integers for any Compton amplitude, one obtains the (presumably ridiculous) result that the asymptotic total cross section for photons on any particle is proportional to the square of its charge. An approximate dynamical calculation is given which relates the coupling of photons to the Pomeranchuk trajectory with the derivative of the trajectory at $t$=0. This yields a prediction for the high-energy total cross section of photons on protons which is consistent with present data. The convergence of the Drell-Hearn sum rule is discussed; it is argued that even with cuts in the angular momentum, the sum rule will converge. Certain sum rules of Bég and of Pagels and Harari are discussed briefly.

Phys. Rev. D 2, 953 - 955 (1970)

# Fixed Poles in High-Energy Compton Scattering, Electroproduction, and the Vector-Dominance Models

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Received 17 April 1970
It is shown that the vector dominance of *s*-channel helicity amplitudes requires the existence of a nonsense wrong-signature fixed pole at $J=1$ in virtual photon-hadron scattering. Furthermore, in the amplitudes for electroproduction, where the virtual photon masses are spacelike, it is argued that such fixed poles must exist simply from such general requirements as analyticity, gauge invariance, and positivity of cross sections. This fixed pole occurs multiplicatively with the Pomeranchuk pole if the photon-hadron cross sections $\sigma L$ or $\sigma S$ are constant asymptotically with energy. A minimal amount of analyticity then allows one to extend this result to general values of the virtual photon masses. If the asymptotic cross section for photoproduction of $\rho$ mesons is dominated by Pomeranchuk exchange and if it conserves helicity, then the multiplicative fixed pole is present there, too. Further, the presence of this fixed pole tests for the compositeness of the $\rho$ meson or third-double-spectral-function effects.

# Multiperipheral Dynamics at Nonvanishing Values of Momentum Transfer*

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Received August 12, 1969

The equation for the absorptive part of the forward elastic scattering amplitude derived by Chew and De Tar as a quadrature on the manifold of the Lorentz group is generalized to include the nonforward absorptive part. An integral equation is derived which is diagonalized by expansion into the irreducible representations of the subgroup of the homogeneous Lorentz group, $SO(2, 1)$. Explicit calculations of the irreducible representations of $SO(2, 1)$ or its covering $SU(1, 1)$ with respect to a noncompact basis $O(1, 1)$ are presented in detail.

Phys. Rev. D 2, 2241 - 2254 (1970)

# Particle Size and Contraction at High Velocity

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Received 27 May 1970

The question of size and contraction of size at high velocity is considered in the context of particle physics. Size is defined through a simultaneous interaction with an external potential. To second order in the external potential, one is led to consider matrix elements of the form $\langle p|j_0(x, x_3, 0)j_0(0)|p\rangle$. For large $p$ such matrix elements are found to approach $p\delta(x_3)F(x)$ if there are no Regge singularities at $J=1$ when $t=0$. If there are such singularities at $J=1$ when $t=0$ and if they recede below $J=1$ for negative $t$, then matrix elements analogous to the one above, but for $t<0$, approach $\delta(x_3)$ at high velocity. $F(x)$ is related to the residue of a wrong-signature fixed pole at $J=1$ in a virtual Compton amplitude. $F(x)$ is also shown to be equal to the second-order impact factor in the operator droplet model. These results are then generalized to an arbitrary number of interactions with the external potential. More singular interactions, where the above analysis breaks down, are considered. It is found that for a certain strength of singularity on the light cone, the particle size may shrink to zero at high velocities. In a large class of models which give the scaling law for deeply inelastic electroproduction and have a constant asymptotic total cross section for electroproduction, it is found that the particle size does not shrink. A converse statement is also found, in that a simple argument shows that if electromagnetic particle size at $t=0$ shrinks, then the total asymptotic electroproduction cross section vanishes at high energy.

PHYSICAL REVIEW D VOLUME 4, NUMBER 6 15 SEPTEMBER 1971

# Anomalous Short-Distance Behavior of Quantum Field Theory: A Massive Thirring Model*

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(Received 19 April 1971)

The anomalous short-distance behavior of the products of quantum field operators, of the sort found in the Thirring model, is investigated. This is done by studying a modified Thirring model, based on a massive Fermi field $\psi(x)$, from several points of view in perturbation theory. This model has the same scaling short-distance behavior as the massless Thirring model. A modification is also constructed in which $\psi(x)$ is an isotopic-spin doublet in two dimensions. This model does not scale at short distance. Our main conclusion is that the massive Thirring model scales at short distance because the special form of the interaction yields no charge renormalization. Further, this interaction allows a kind of gauge transformation under which $S$-matrix elements and current matrix elements are unchanged but which changes the scaling dimension. Thus, no physical significance can be attributed to this anomalous dimension.

$$\mathfrak{L}_{\text{int}}(x) = \tfrac{1}{2}gZ_1 :\bar{\Psi}(x)\gamma_\mu\Psi(x)\bar{\Psi}(x)\gamma^\mu\Psi(x): - \delta m :\bar{\Psi}(x)\Psi(x):$$

$$+ (Z_2 - 1)\times \tfrac{1}{2}i :\bar{\Psi}(x)\gamma_\mu\partial^\mu\Psi(x) - \partial^\mu\bar{\Psi}(x)\gamma_\mu\Psi(x): .$$

$$\left(m^2\frac{\partial}{\partial m^2}+\beta(g)\frac{\partial}{\partial g}-2\gamma(g)\right)G^{-1}(p^2/m^2,g)\sim 0.$$

C-S equation requires

$$G(q^2) \approx (q^2)^{\alpha(g)}$$

$$\beta(g)\frac{d\alpha(g)}{dg} = 0$$

PHYSICAL REVIEW D VOLUME 5, NUMBER 8 15 APRIL 1972

# Nonplanar Couplings in the Triple-Regge Vertex*

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(Received 3 December 1971)

Recently zeros have been found at $\alpha_V(0) = 2\alpha(t) - 1,\ 2\alpha(t) - 2, \ldots$ in the triple-Regge vertex involving $\alpha_V(0)$-$\alpha(t)$-$\alpha(t)$. Such zeros were found both in a dual-resonance model and in certain classes of Feynman graphs. We have examined this question in a model of nonplanar Feynman graphs and found zeros at $\alpha_V(0) = 2\alpha(t) - 2,\ 2\alpha(t) - 4, \ldots$ but not at $\alpha_V(0) = 2\alpha(t) - 1,\ 2\alpha(t) - 3, \ldots$. In particular, the zero involving the triple-Pomeranchukon coupling at $t = 0$ is not present.

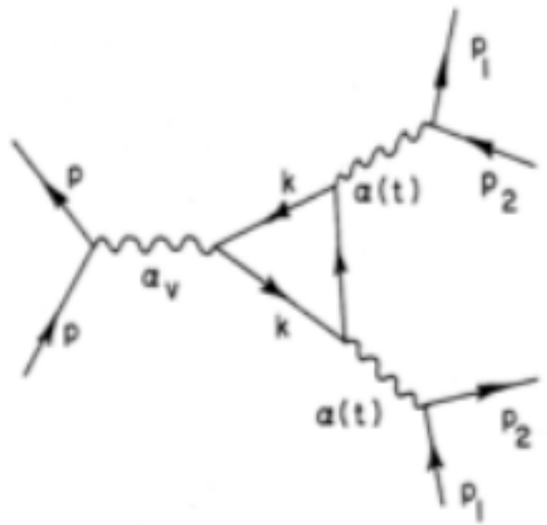


FIG. 5. Planar triple-Regge coupling.

$$\propto \sin(\pi[\alpha_v(0) - 2\alpha(t))$$

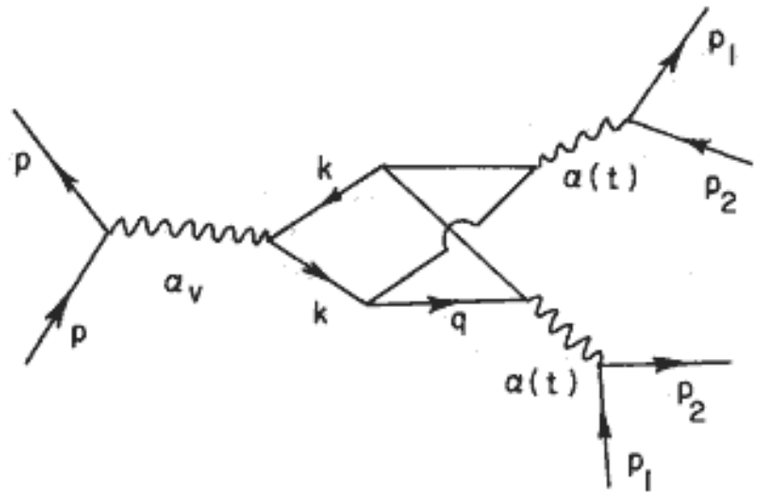


FIG. 6. Nonplanar triple-Regge coupling.

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# $O(2,1)$ Analysis of Single-Particle Spectra at High Energy*

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Processes of the type proton+proton → pion+anything at high energy are discussed. The differential cross section for such reactions is expressed in terms of a three-particle → three-particle amplitude. This amplitude is then expanded into $O(2,1)$ representations. If the Pomeranchuk trajectory is the dominant $O(2,1)$ singularity at high energy, the existence of pionization and limiting fragmentation is obtained. Furthermore, the pionization products are essentially independent of the target and projectile, while the fragments of the target are independent of the projectile. Modifications in the presence of strong Regge cuts at $J=1$ are discussed.

# ON THE FACTORIZATION OF THE POMERANCHUK SINGULARITY IN THE MUELLER-REGGE DIAGRAMS

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Received 27 August 1974

It is shown that the $j$ plane singularity (Pomeron) which leads to a rising total cross-section like $(\ln s)^\epsilon$, $\epsilon > 0$, cannot be factorizable in the Mueller diagrams for inclusive production of particles with large rapidity differences. The relevance of this result for the theories of a renormalized Pomeron is discussed.

The discovery of a rising cross-section in pp collisions at the ISR suggests that the scattering amplitude $A(s, t)$ has an asymptotic behaviour of the form $A(s, t) \sim Cs^{\alpha_p(t)}(\ln s)^\epsilon$, $s \to \infty$, $\alpha_p(0) = 1$, $0 < \epsilon \leqslant 2$. The exact value of $\epsilon$ is model dependent and the coupling $C$ is factorized on the basis of general arguments based on $t$ channel unitarity [1]. This form corresponds to a rising cross-section like $\sigma_t \sim (\ln s)^\epsilon$ for $s \to \infty$. We expect that the rising of the total cross-section leads in general to a violation of scaling in the inclusive spectra due to the exchange of this leading singularity in the Mueller diagrams [2] of fig. 1a.

In this note we want to show that Regge singularities leading to a rising cross-section $\sigma_t$ cannot be factorizable in the Mueller diagrams since this is not allowed by positivity. In fact, consider the model in

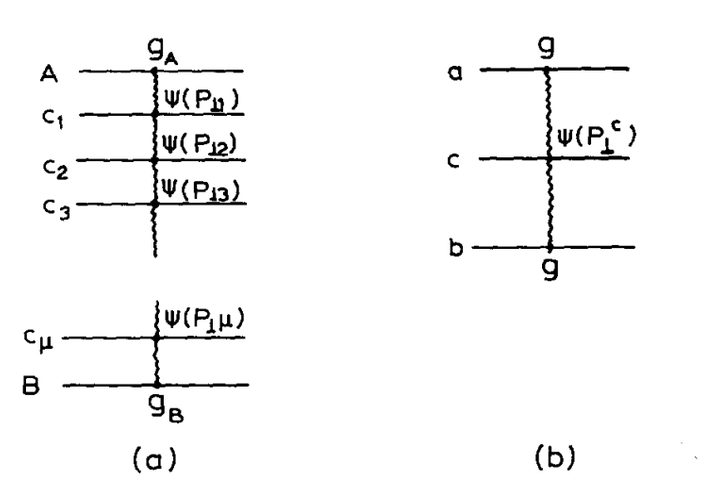


Fig. 1. a) The Mueller diagram for the inclusive distribution of $\mu$ identical particles with large rapidity differences. b) The Mueller diagram for the one particle inclusive distribution in the central region.

# Happy Birthday, AI!